A STUDY ON SOME PID TUNING METHODS USING SIMULATION

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By

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Certificate

This is to Certify that the thesis titled "A STUDY ON SOME PID TUNING METHODS USING SIMULATION", Submitted by Mr. DAKKAMADUGULA RAVI (110EE0222) has been carried out under my supervision in partial fulfilment of the Requirements for the degree of Bachelor of technology in ELECTRICAL ENGINEERING. NATIONAL INSTITUTE OF TECHNOLOGY, Rourkela and is a reliable and genuine work carried out by him under my supervision.

To the best of information, this work has not been submitted to any other university/institute for the award of any degree or diploma

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ABSTRACT

PID controllers are by and large generally utilized as a part of the industry because of their all-around grounded established, effortlessness, support prerequisites, and simplicity of returning to the web. In the previous four decades, there are various papers managing, tuning of PID controller. Designing a PID controller to meet phase margin and gain margin detail is a surely understood configuration procedure. If the phase and gain are not determined deliberately, then the outline may not be ideal as I could be the large phase margin that could give better execution. This paper studies about the relationship between ISE execution list, phase and gain margin and analyzes two tuning methods, in light of these three parameters. These tuning methods are especially valuable in the setting of control and tuning, where the control parameters must be calculated on-line.

In the last piece of the work, thorough study has been done in few different PID controller tuning methods. Results of simulation, plots, graphs, indicate the validity of the study. All simulations have been done in SIMULINK software of MATLAB.

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CHAPTER 1

INTRODUCTION

A proportional-integral-derivative(PID controller) controller is one of the widely used controllers in industries for controlling feedback systems. PID controllers are sold in large quantities and are often the solution of choice when a controller is needed to close the loop. The reason PID controllers are so popular is that using PID gives the designer a larger number of options and those options mean that there are more possibilities for changing the dynamics of the system in a way that helps the designer. More over, other than producing the control activity, the same computerized PC can be utilized for various different applications. PID controller measure an error value also called actuating signal which is the difference between a measured the output value and a desired value.

Figure.1block diagram for control system

OPEN-LOOPCONTROLL SYSTEM:

Open-loop system is called as control system without feedback or non-feedback control system. Control characteristics of open-loop systems are independent of the output of the system.

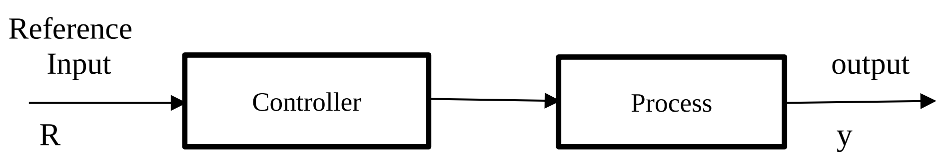

Figure.2 block diagram for open loop control system

Two components in a open-loop system that are controller and controlled process. An input is applied to the controller and the output of the controller gives to the controlled process and we get the desired output. Open-loop control systems are simple to design and hence economical. It reauire lessvmaintenance but, these systems are inaccurate.

Examples of open-loop syetem

- A field control dc motor.
- Automatic traffic control.

CLOSED-LOOP SYSTEM:

Open-loop system in which controlling action or input depends on output. It means present output depends upon input and previous output.this type of system is called closed-loop system.

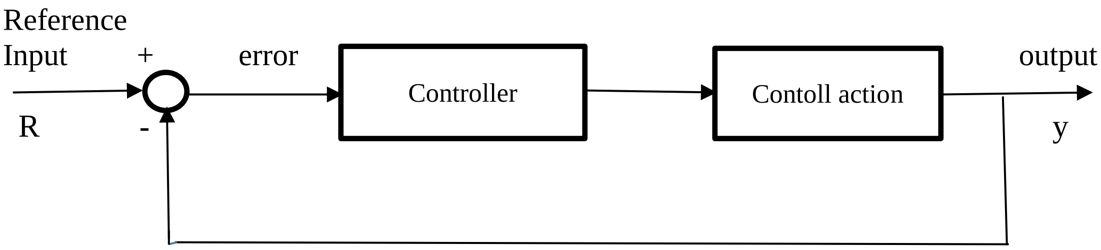

Figure.3 block diagram for Closed loop system

These systems are accurate and reliable. These systems are moderately more complex in structure and hence it adds upto the cost construction it higher than the open loop. Open-loop control systems are faster and reduced effect of parameter variation.

Examples of closed-loop system

- Dc motor speed control.
- Radar tracking system.

PID controllers can be designed as three terms, P control, and I control and D control-combined together Proportional-integral-derivative terms are so popular is that using PID gives the designer a more number of options. The output of the PID controller u(t) can be expressed in terms of the input e(t), as:

$$u(t) = k_p[e(t) + \tau_d \frac{de(t)}{dt} + \frac{1}{\tau_i}\int_0^t e(\tau)d\tau] \quad (1)$$

The transfer fuction is denoted by:

$$C(s) = K_p(1 + \tau_d s + \frac{1}{\tau_i s}) \quad (2)$$

The terms of the controller are defined as:

K_p = proportional gain, τ_d = Derivative time, and τ_i = Integral time.

In the following sections we shall try to understand the effects of the individual components- proportional, derivative and integral on the closed loop response of this system.

1.1 PROPORTIONAL CONTROLLER:

Proportional control is easy and universal method of control of many kind of systems. linear feedback control system. In proportional controller mode, the controller simply multiplies the error by the proportional gain (k_p) to ge. The block diagram proportional control as shown.[2].

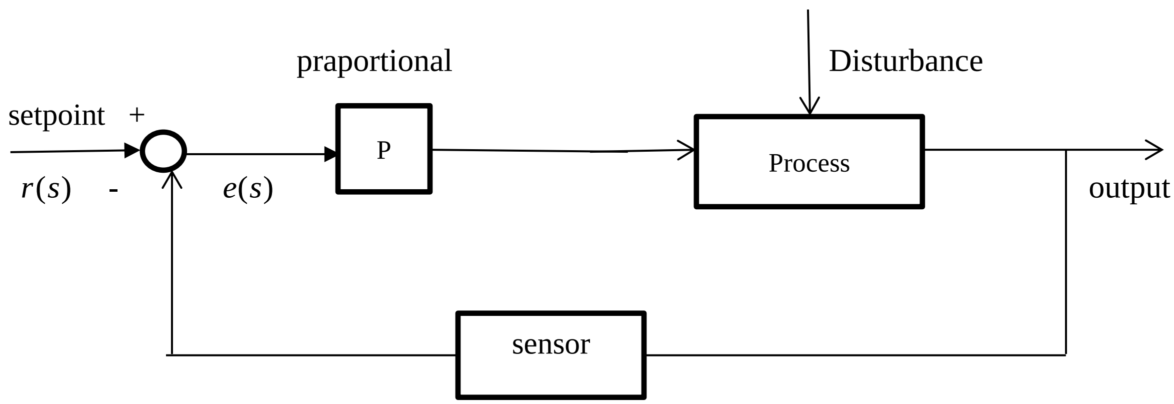

Figure.4 Proportional Controller

$U(t)=K_p e(t)$ (3)

Where,

K_p = proportional gain

1.2 INTEGRAL CONTROLLER:

. Integral control gives an desired value which is proportional to the time I of the error. It is also called reset control. It is possiable to use I controller itself.

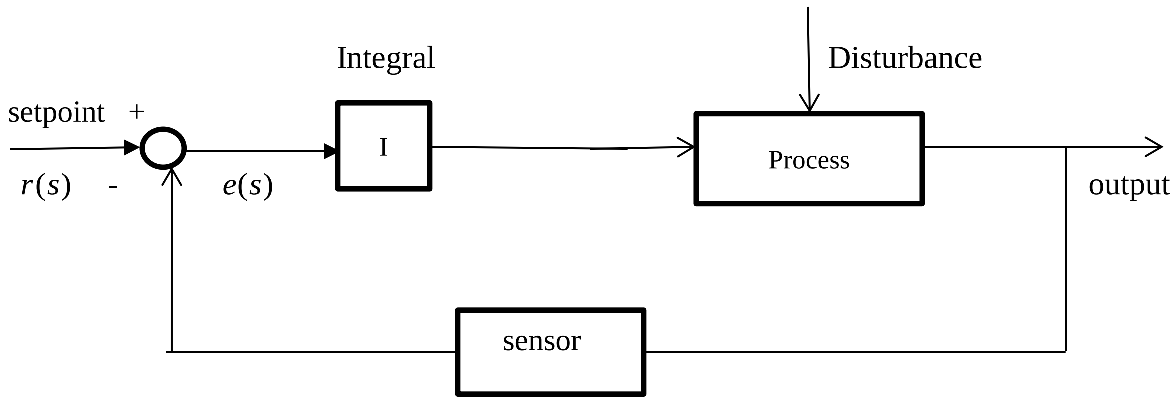

Figure.5 Integral controller

$$U(t) = K_i \int_{\infty}^{0} e(t)dt \tag{4}$$

.Activity by a control component that rolls out improvements to the inputs of an assembling procedure in view of the amassed mistake more than a time of time. Indispensable activity controllers are frequently utilized as a part of conjunction with corresponding controllers, which roll out restorative improvements in extent to the measure of mistake in an information, all together make data conformities quicker and more precise With essential activity, the controller yield is relative to the measure of time the blunder is available. Basic activity wipes out counterbalance that remaining parts whenproportional control is used.[2]

1.3 DERIVATIVE CONTROLLER:

The PID controller is not realizable because we cannot calculate the D part (that is, the derivative of the error) for the given present and past error (note that "realization" is defined under the condition that the derivative is not available and only the present and past error are available). But, from practical point of view, the D part of the proportional integral derivative controller can be realized by backward numerical D with the sampling time of the PID controller. Of course, using the numerical derivative with the nonzero sampling time is an approximation of the D part. The derivative controller block diagram as shown.[1]

The derivative term is given by:

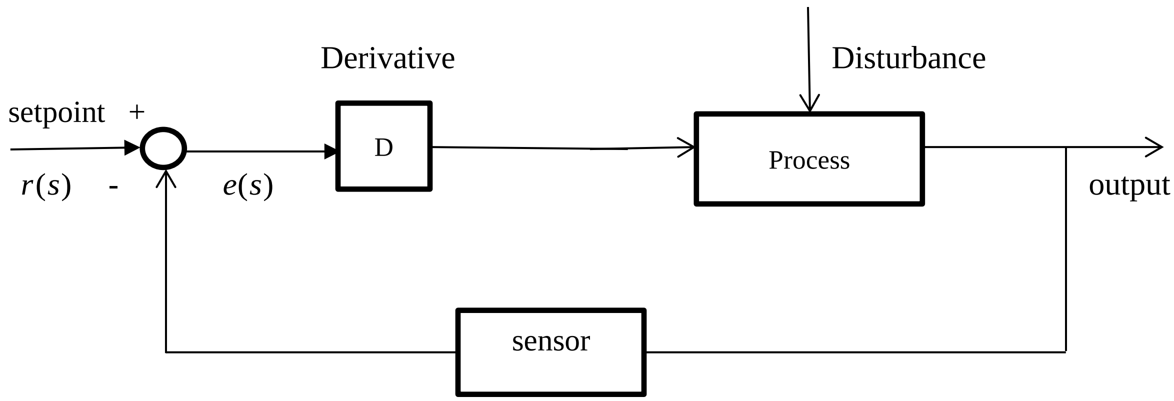

Figure.6 Derivative controller

$$U(t) = K_d \frac{d}{dt} e(t) \tag{5}$$

It is used alone because it cannot produce output. When error is constant, output returns to its normal. Derivative controller can be thought of as desgin smaller one gets close to the right value, and then stopping in the correct region, rather than design further changes. Derivative active quantifies the need to apply more change by linking the amount of change applied to the rate of change needed.[2]

1.4 PROPORTIONAL DERIVATIVE CONTROLLER:

In proportional derivative controller mode,the controller make the following: Multiplies the error by the proportional gain (k_p) and added to the derivative error multiplied by $k_{d,}$ to get the controller output.[2]

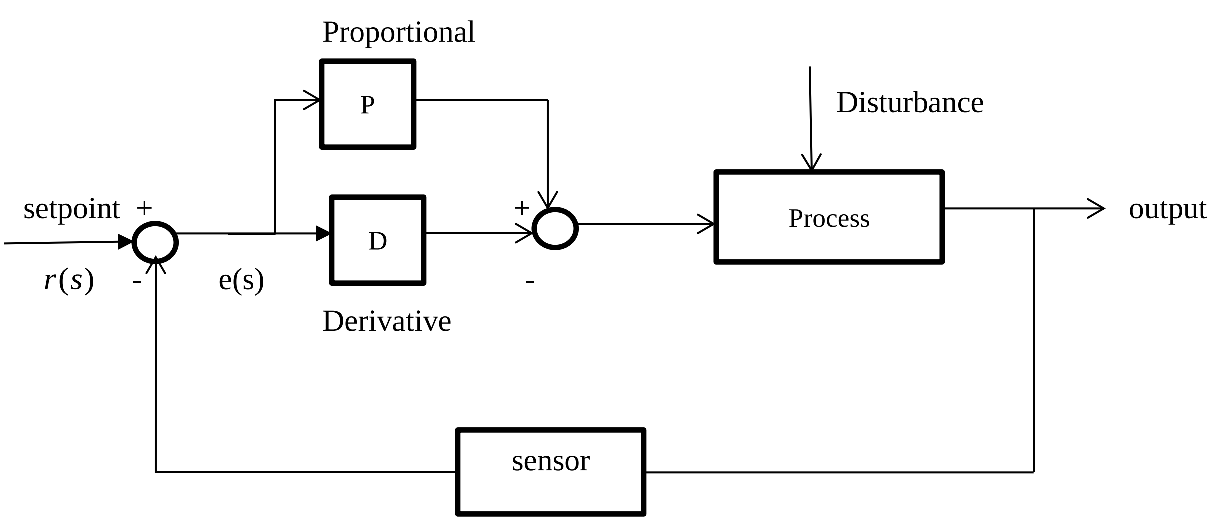

Figure.7 PD controller

The real PD controller according to Equation with has a smaller maximum overshoot due to the 'faster' D action compared with the controller types mentioned.

Maximum overshoot is reduced, steady-stste error not effected, natural frequency remain change

1.5 PROPORTIONAL INTEGRAL CONTROLLER:

Proportional integral controller is a one type of the proportionai-intrgral-derivative controller in which the derivative control of the error is not used. In proportional integral controller, the controller make the following.

Multiplies the error by the proportional gain k_p and added to the integral error multiplied by $k_{i,}$ to get the controller output.[2]

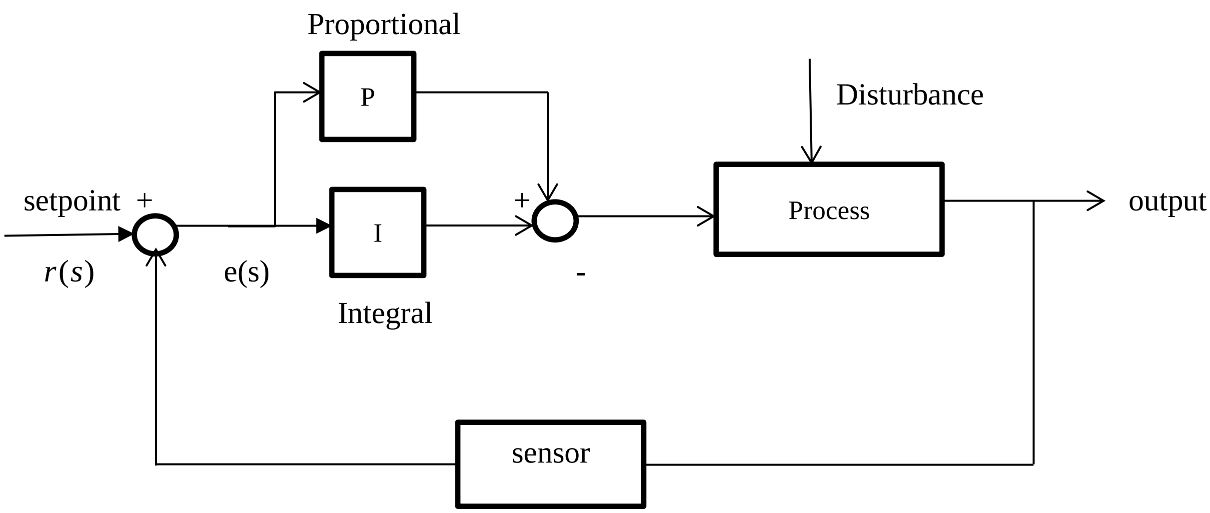

Figure.8 PI controller

$$U(t) = K_p e(t) + K_i \int_{\infty}^{0} e(t)dt \quad (7)$$

1.6 PROPORTIONAL INTEGRAL DERIVATIVE CONTROLLER:

PID controller [2] is one of the common algorithms used for control systems. It is widely used because the algorithm does not involve higher order mathematics, but still contains many variables.

Tuning of the 3 parameters in the PID controller, the controller can give control activity coveted to prerequisites. The reaction of the controller can be portrayed as far as the responsiveness of the controller to a slip, the extent to level of system swaying. In any case, we ought to comprehend that the utilization of the PID calculation for control does not ensure ideal control of the system or system solidness,

$$U(t) = K_p e(t) + K_i \int_0^t e(k)dk + Kd \frac{de(t)}{dt} \tag{8}$$

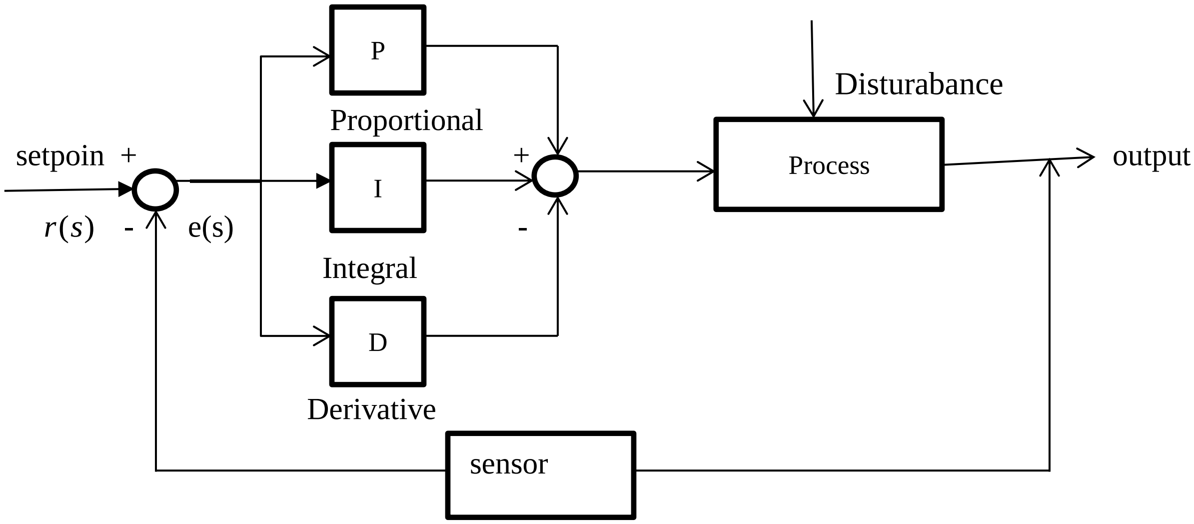

Figure.9 PID controller

The above piece outline and comparison demonstrate the PID controller conduct in time area structure. The time, space examination is utilized for ongoing results and to focus different addition parameters like ascent time, top overshoot and consistent state lapse and so on. Then again, there is another type of representation that aide in deciding the execution parameters like stability and phase margins etc

Representation of Transfer function:

$$G(s) = Kp + \frac{Ki}{s} + Kds \tag{9}$$

or

$$= Kp(1 + Tds) \tag{10}$$

1.7 Motivation:

. I am inspired by the way that current control engineering manages enhancing assembling procedures, of the sufficient utilization of Proportional Integral Derivative (PID) controllers in procedure industry, there dependably has been a huge attempt to acquire viable PID controller configuration systems. PID controller design is one of the modern reseach fields in present days.The present days challenge of the project and the latest technology study is the motivation behind the project.

1.8 OBJECTIVES:

In this project, the obejective is to explore the of the by developing PID any input signal and to get desired output signal for any appilication.

Thesis project will include:

1.Ziegler-Nichols method tuning method

2.Chine –Hrones - Reswick Pid tuning method

3. Cohen –Coon tuning method tuning method

4. Optimal PID controller design

1.9 STRUCTURE OF THESIS:

- I discussed here indtroduction of PID controller , Each control system intended for a determination or particular application are needs to meet certain execution particulars.
- A controller can utilize both of these terms or their mixes, on the other hand, indispensable and subsidiary control are accomplished alongside corresponding control.
- I have disscucced here some of the tuning procedures to find the parameters of PID.
- And the following plots for the tuning procedures is been shown under .

1.10 LITERATURE REVIEW:

A proportiona lintegral derivative controller is one of the widely used controllers in industries for controlling feedback systems. The PID controller can give control activity coveted to prerequisites. The reaction of the controller can be portrayed as far as the responsiveness of the controller to a slip, the extent to level of system swaying. In any case, we ought to comprehend that the utilization of the PID calculation for control does not ensure ideal control of the system or system solidness. The error is controlled or reduced by manipulating /adjusting the inputs that the PID controller receives and thus it produces a command signal to the plant for error correction. Minimizing the integral performance criteria such as $ISE, ISTE, IST^2E$ the controller parameters are determined. The results were compared to those obtained with the Ziegler–Nichols settings. Satisfactory performances were obtained over a wide range of linear integrating processes.

CHAPTER 2

SOME TUNING PROCEDURES:

Plant considered:

$$G(s) = \frac{0.3972}{1.365+1} e^{-0.755} \quad (11)$$

In this an optimal technique for tuning Pi controller parameters for FOPDT models proposed.simulation studies for three common examples showed that the proposed method. Comparing the proposed method with well-known techniques,suggested that the prposed method was advantages to most of them such s Ziegler-Nicchols, Chine –Hrones – Reswick and Cohen-Coon methods.[6]

2.1 Ziegler-Nichols tuning method:

Best known and most widely used. This method work by generating a process variable response curve to step in control output. In control planning, a proportional integral controller is a feedback controller which drives the plant to be controlled by a biased entire of the slip and the essence of that regard. Generate step response, calculate change in control output, change in process variable. It is an uncommon case of the proportional integral derivative controller in which the subordinate (D) some bit of the bumble is not used.[10]

Ziegler-Nichols tuning formula

Table.1Ziegler-Nichols tuning formula

Type controller	Step response			Frequency response		
	K_p	T_i	T_d	K_p	T_i	T_d
P	1/a			0.5Kc		
PI	0.9/a	3L		0.4Kc	0.8Tc	
PID	1.2/a	2L	L/2	0.6Kc	0.5Tc	0.12c

Here only using step response controller parameters are found out. Then using Simulink output step response the model plant is taken.

a = 0.189221 P = 5.129 PI = $4.606(1+\frac{1}{2.565s})$

PID = $6.1275+\frac{3.570}{s}+\frac{2.5829N}{1+N/s}$

2.2 The Chien–Hrones–Reswick (CHR) tuning method:

The Chien–Hrones–Reswick (CHR) [10] strategy underlines the set-point unsettling influence dismissal. Likewise, one subjective determinations on the reaction overshoot and speed can be obliged. Contrasted and the customary Ziegler–Nichols tuning equation, the CHR strategy utilizes the period consistent T of the plant expressly. The CHR PID controller tuning recipes are condensed in for set point regulation. The all the more intensely damped shut circle reaction, which guarantees, for the perfect plant, the speediest reaction without overshoot is marked with 0% overshoot, and the fastest reaction with 20% overshoot is named with 20% overshoot. In this technique the procedure response bend is acquired first and foremost, by an open circle test as demonstrated in Figure, and afterward the methodology motion is approximated by a first request in addition to dead time model, with taking after parameters.

$$\tau_m = \frac{3}{2}\left(\frac{\tau 2 - \tau 1}{1}\right) \tag{12}$$

This system that proposed by Dr C. L. Smith provides a decent rough guess to procedure response bend by 1st request in addition to dead time show After deciding of 3 parameters of km, $\boldsymbol{\tau}_{m}$, and d, the controller parameters can be gotten, utilizing C-C relations given in the table. These relations are created observationally it give shut circle reaction a ¼ decay ratio

Chine –Hrones – Reswick Tuning Method:

Table.2 Chine –Hrones - Reswick PID tuning method

Controller type	With 0% overshoot			With 20% overshoot		
	K_p	T_i	T_d	K_p	T_i	T_d
P	0.3/a			0.7/a		
PI	0.35/a	1.2T		0.6/a	T	
PID	0.6/a	T	0.5L	0.95/a	1.4T	0.4L

set point regulation:

For 0 % overshoot P controller: K_p =1.47 PI controller: K_p = 1.0749 , T_i=0.89441

PID controller: K_p = 2.314, T_i= 1.27 , T_d=.33

For 20 % overshoot P controller: K_p =2.67 PI controller: K_p = 2.14, T_i=1.27

PID controller: K_p = 3.968, T_i=1.81, T_d=.302

Disturbance rejection:

For 0 % overshoot P controller: K_p =1.469 PI controller: K_p = 2.14, T_i=2.42

PID controller: K_p = 3.97, T_i= 2.052, T_d=.26

For 20 % overshoot P controller: K_p =3.56 PI controller: K_p = 3.56, T_i=1.867

PID controller: K_p = 5.175, T_i= 1.71, T_d=.26

2.3 Cohen –Coon tuning method:

The Cohen-Coon[7] tuning tenets are suited to a more extensive mixture of courses of action than the Ziegler-Nichols tuning standards. The Ziegler-Nichols principles function admirably just on courses of action where the dead time is not as much as a large portion of the length of the time steady. The Cohen-Coon tuning standards function admirably on procedures where the dead time is the under 2 times the length of the time steady (and you can extend this much further if needed). Cohen-Coon gives one of the couple of sets of tuning decides that has rules for PD controllers – if you ever require this another Ziegler–Nichols sort tuning calculation is the C–C tuning method.

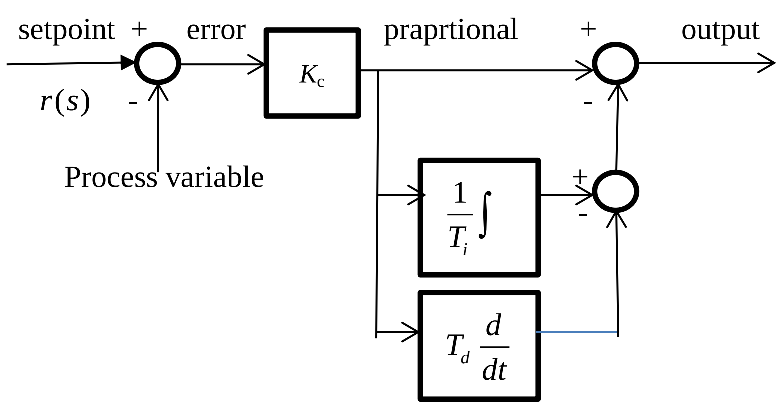

Figure.10 block diagram of Cohen-Coon

Cohen-Coon Tuning algorithm**:**

$$a = \frac{KL}{T} \tag{13}$$

$$\tau = \frac{\boldsymbol{L}}{\boldsymbol{L+T}} \tag{14}$$

Table.3 Cohen-Coon Tuning algorithm

Controller type	K_p	T_i	T_d
P	$\frac{1}{a}(1+\frac{3.3-3\boldsymbol{\tau}}{1+1.2\boldsymbol{\tau}})$	$\frac{3.3-3\boldsymbol{\tau}}{1+1.2\boldsymbol{\tau}}$	
PI	$\frac{0.9}{a}(1+\frac{0.92\boldsymbol{\tau}}{1-\boldsymbol{\tau}})$	$\frac{3.3-3\boldsymbol{\tau}}{1+1.2\boldsymbol{\tau}}L$	
PD	$\frac{1.24}{a}(1+\frac{0.13\boldsymbol{\tau}}{1-\boldsymbol{\tau}})$		$\frac{0.27-0.36\boldsymbol{\tau}}{1-0.87\boldsymbol{\tau}}L$
PID	$\frac{1.35}{a}(1+\frac{0.18}{1-\boldsymbol{\tau}})$	$\frac{2.5-2t}{1-0.39\boldsymbol{\tau}}L$	$\frac{0.37-0.37\boldsymbol{\tau}}{1-0.81\boldsymbol{\tau}}$

P controller: K_p = 5.3746, PI controller: K_p =6.416, T_i=1.245,

PD controller: K_p = 6.019, T_d= .1587,

PID controller: K_p= 6.865, T_i= 1.64, T_d= 0.3757

2.4 Optimal PID controller design:

The measure of the quality of the transient reaction of a PID controller can be performed by calculating an integral performance.

. Consider the general equation is given by,

$$jn(\theta) = \int [t^n E(\theta,t)]^2 dt \tag{15}$$

Where

e(θ, t) is the error signal which enters the PID controller, with θ the PID controller parameters. Two setting strategies for PID controller are proposed.[9]

Set-point optimum PID tuning

For PI controller

$$Kp = \frac{a_1}{k}\left(\frac{L}{T}\right)b_1 \,,\; T_i = \frac{T}{a_2+b_2\left(\frac{L}{T}\right)} \qquad (16)$$

For PID controller

$$Kp = \frac{a1}{k}\left(\frac{L}{T}\right)^{b1},\; T_i = \frac{T}{a2+b2\left(\frac{L}{T}\right)} \,,\; T_d = a3{*}T\,\frac{a1}{k}\left(\frac{L}{T}\right)^{b3} \qquad (17)$$

PI Controller

Table.4 Optimal PI controller

Criterion	K_p	T_i	T_d
ISE	3.469	2.000	
ISTE	2.529	1.578	
IS$\boldsymbol{T^2}$E	2.130	1.398	

PID controller

Table.5 Optimal PID controller

Criterion	K_p	T_i	T_d
ISE	3.726	1.315	0.340
ISTE	3.704	1.529	0.211
IS$\boldsymbol{T^2}$E	3.446	1.568	0.240

PID controller with D in feedback path

Table.6 PID controller with D in feedback path

Criterion	K_p	T_i	T_d
ISE	4.479	2.124	0.238
ISTE	3.804	2.074	0.211
IS$\boldsymbol{T^2}$E	3.398	1.882	0.176

For disturbance rejection:

PI Controller:

Table.7 Disturbance rejection for PI controller

Criterion	K_p	T_i	T_d
ISE	1.358	1.846	
ISTE	1.153	1.458	
IS$\boldsymbol{T^2}$E	1.158	1.581	

PID Controller:

Table.8 Disturbance rejection for PID controller

Criterion	K_p	T_i	T_d
ISE	1.593	0.760	0.382
ISTE	1.569	1.032	0.289
IS$\boldsymbol{T^2}$E	1.675	0.892	0.264

CHAPTER 3

SIMULATION PLOTS AND RESULTS:

Simulation is done using Simulink. Using tuning formula we have found out P, PI, PD and PID controller parameters. Response for FOIPDT plant modal is observed for different value of filter coefficient 'N'.

3.1 Ziegler Nichols plots:

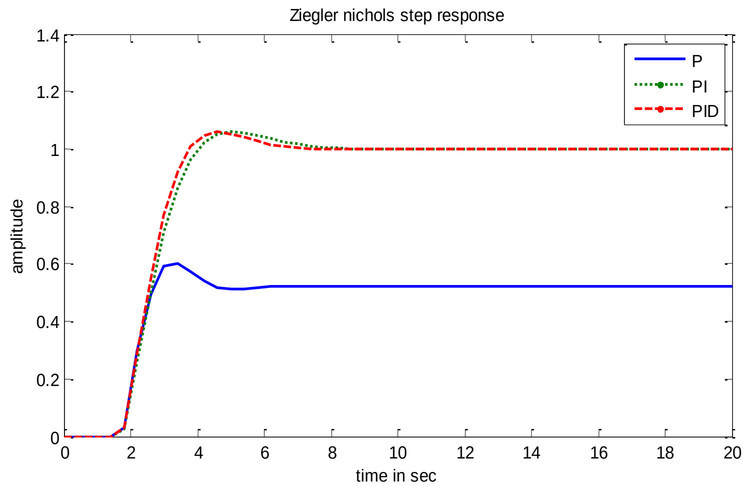

Figure-11 Ziegler-Nichols step response

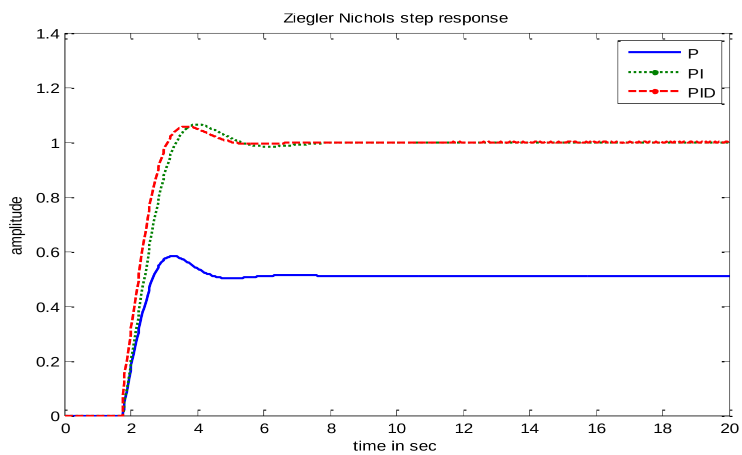

Figure-12 Ziegler-Nichols step response

So one can see that small value of 'N' increase overshoot, settling time and oscillation, but reduce the rise time for PID controller. PI controller is eliminating the error, but P controller is giving offset.

3.2 Chine -Hrones-Reswick plots:

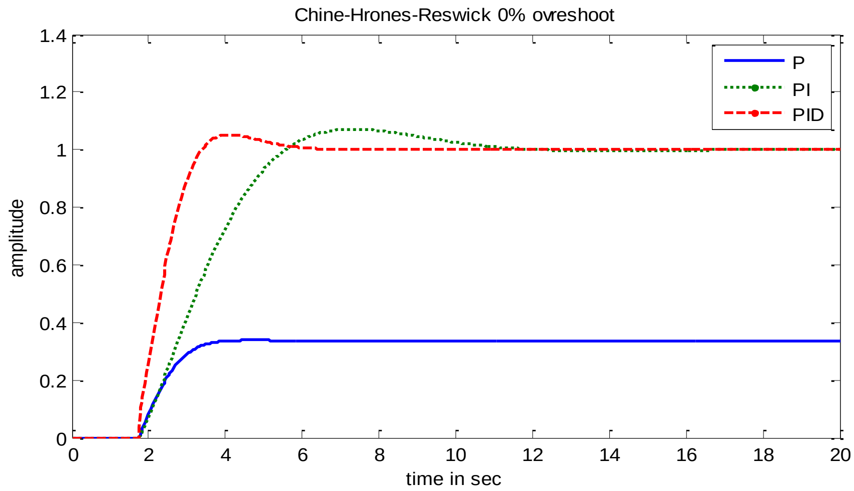

Figure-13 Chine- Hrones-Reswick 0% overshoot

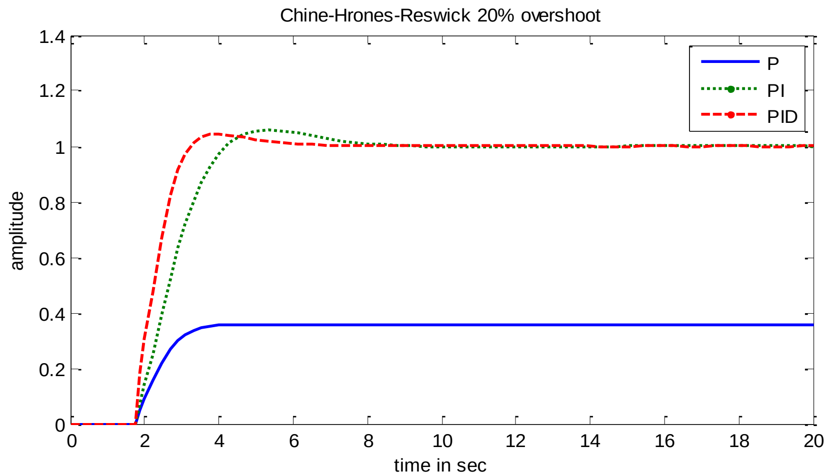

Figure-14 Chine-Hrones-Reswick 20% 0vershoot

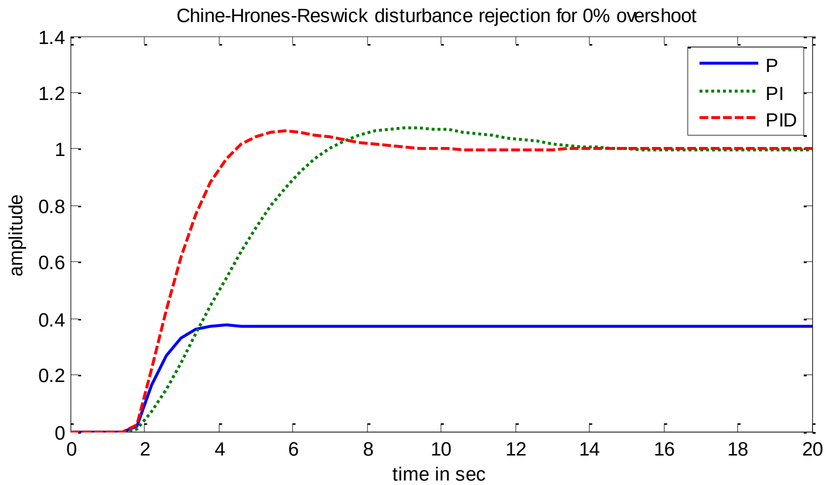

Figure-15 Chine-Hrones-Reswick disturbance rejection for 0% vershoot

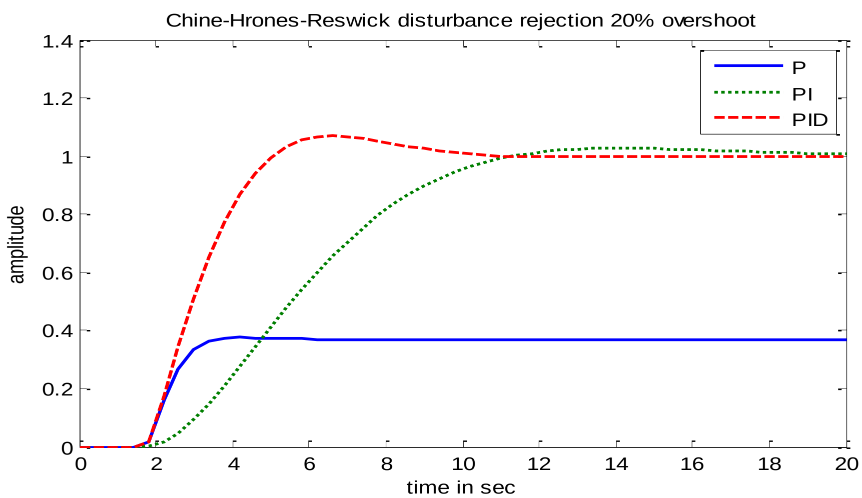

Figure.16 Chine-Hrones-Reswick disturbance rejection for 20% vershoot

Here we can see that small value ofincrease overshoot, settling time and oscillation, but reduce the rise time for PID controller. PI controller is eliminating the error, but P controller is giving offset. So, PID controller gives the better performance than the PI controller.

3.3 Cohen –Coon plots:

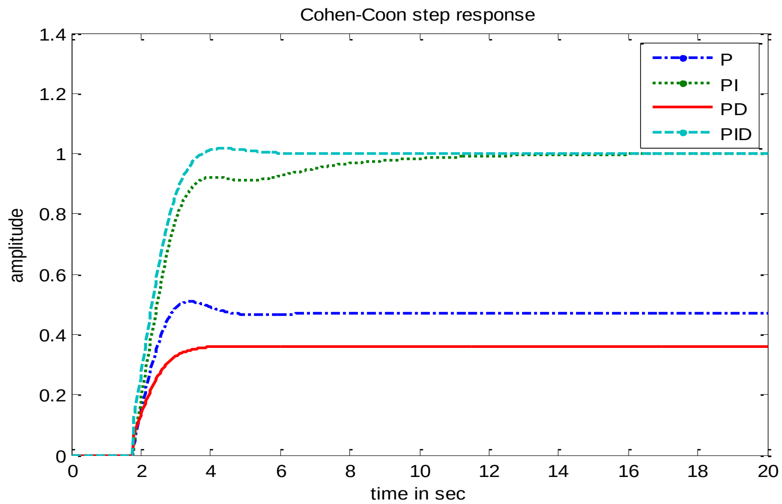

Figure-17 Cohen-Coon step response

3.4 Optimal PID controller design plots:

For set point

PI controller

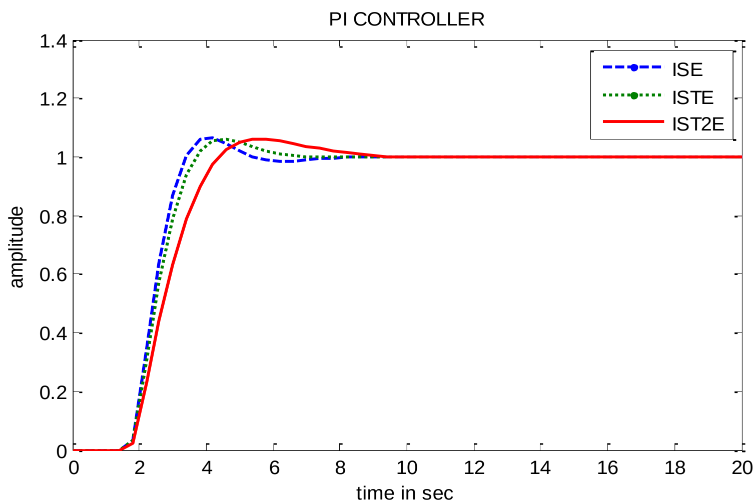

Figure-18 Optimal PI controller response

PID controller:

N=0.1

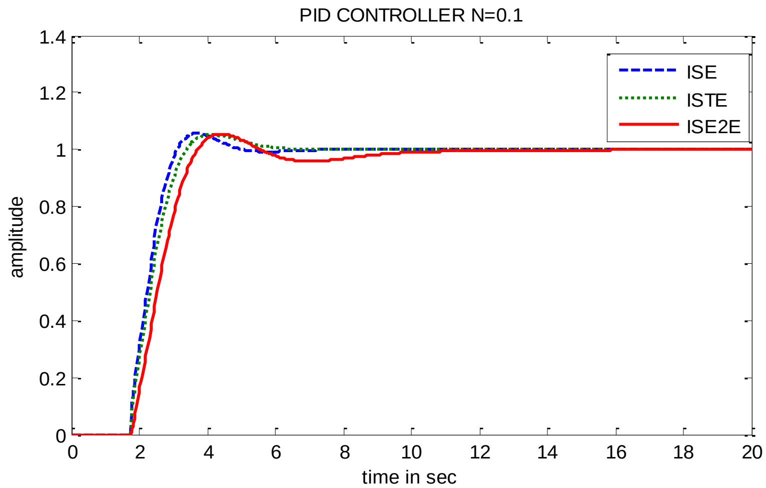

Figure.19 Optimal PID controller for N=0.1

PID controller

N=1

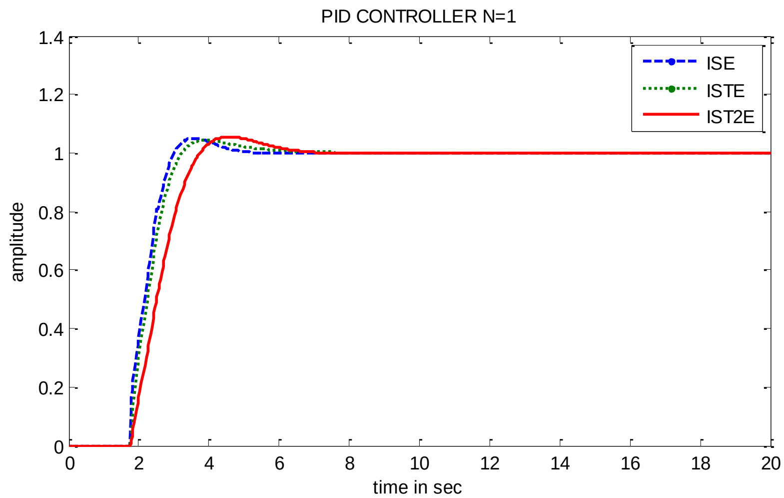

Figure.20 Optimal PID controller for N=1

PID controller with D feedback:

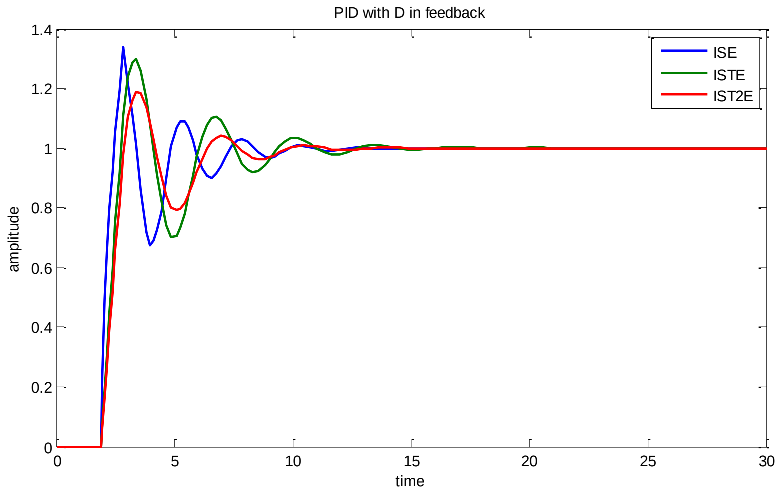

Figure.21 PID controller with D feedback

Disturbance rejection:

PI controller

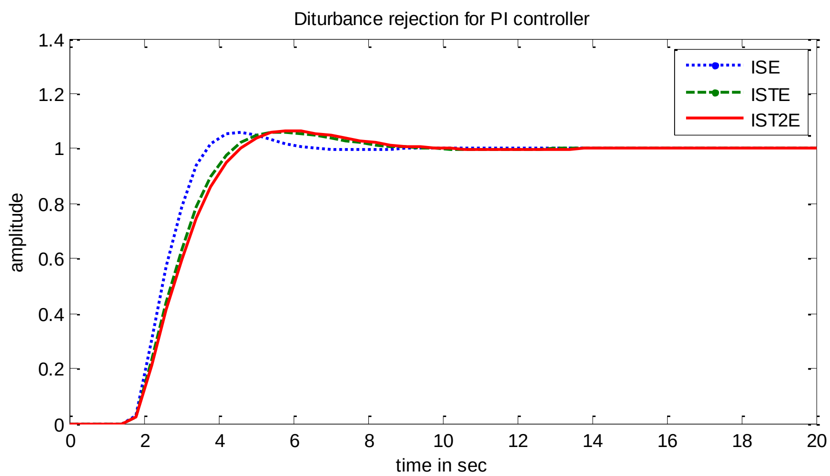

Figure.22 Disturbance rejection for PI controller

PID Controller

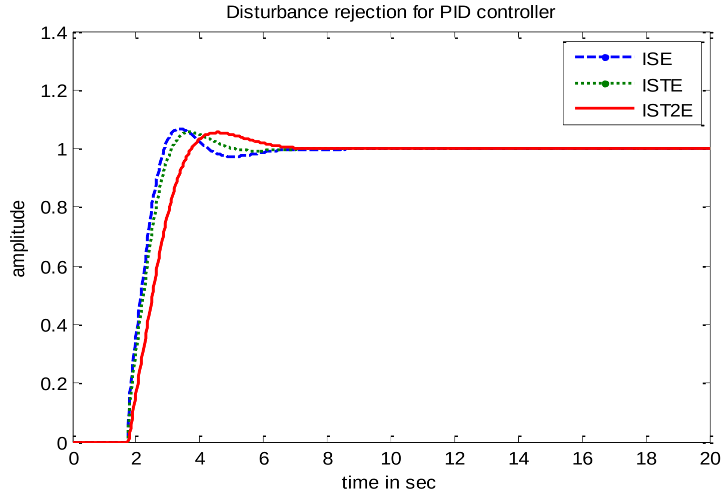

Figure.23 Disturbance rejection for PID controller

CHAPTER 4

CONCLUSION:

Project study on PID controller design for FOPDT plant models provide a brief idea of plant modelling, type of plant model and controllers (P, PI, PD and PID) tuning method used for the model plant. For tuning of controllers of FOPDT Ziegler-Nichols tuning formula, CHR PID tuning algorithm and Cohen-Coon Tuning algorithm are used. Discussed Plant modelling will help in modelling of many industrial plants. And tuning method used for that plant will help to find out the controller parameters.The above tuning methods resulting in good controlling performance and these tuning methods can be used in industrial process control.

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